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THE AMERICAN DOG TICK, EASTERN CARRIER OF ROCKY MOUNTAIN SPOTTED FEVER

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CONTENTS

	Page		Page
Economic importance	1	Life history—Continued.	
Distribution	2	Nymph	17
Hosts	3	Seasonal incidence and overwintering	22
Life history	5	Natural control	23
Adult	5	Artificial control	23
Larva or seed tick	11	Literature cited	25

ECONOMIC IMPORTANCE

The wide distribution of Rocky Mountain spotted fever in the central and eastern portions of the United States, where the American dog tick, *Dermacentor variabilis* (Say), is the principal, if not the only, vector, has made necessary a more complete knowledge of that tick.

Since the discovery, a few years ago, that Rocky Mountain spotted fever is present in the Eastern States and that the American dog tick is the vector of the disease there, this tick has come to be regarded as of great economic importance. In 1911 Maver (*8*)[1] reported the experimental transmission of the western strain of the disease by *Dermacentor variabilis.* Early in 1931 Rumreich, Dyer, and Badger (*13*) identified Rocky Mountain spotted fever in the Eastern States and later in the same year (*3*) reported the experimental transmission of the eastern strain by the American dog tick. Badger (*1*), in 1932, collected naturally infected specimens on a farm in Virginia. A useful summary of the present knowledge of Rocky Mountain spotted fever has been published by Parker (*9*). The number of reported cases of Rocky Mountain spotted fever in the eastern and southern portions of this country averages about 140 per year, with a mortality of about 25 percent. The fear of a disease with such a high mortality rate extends the economic effect of the tick's presence beyond the mere incidence of the disease. This has tended to affect adversely the property values and the resort business in certain localities where ticks are abundant.

The American dog tick has also been associated with other diseases, including tularaemia. Green (*4*) demonstrated the natural occurrence of tularaemia infections in *Dermacentor variabilis* in 1931, and in 1934 Philip and Jellison (*11*) secured experimental transmission with

[1] Italic numbers in parentheses refer to Literature Cited, p. 25.

this species. Human cases attributed to tick bite have now been reported from several States. In 1932 Rees (*12*) reported the experimental transmission of anaplasmosis of cattle by means of the American dog tick. Parker et al. (*10*) have summarized the present knowledge of the relation of *D. variabilis* to disease transmission.

Aside from its disease-transmitting propensities, this tick is important because of the aversion people have to ticks crawling on the clothing and body. Considering the abundance of American dog ticks in many localities, the number of them that attach themselves to man is relatively small. Their attachment, however, frequently results in persistent itching and irritation at the point of attack.

As a pest of dogs *Dermacentor variabilis* ranks high. In heavily infested localities dogs that are allowed free run frequently pick up scores to hundreds of ticks each day. This causes severe irritation, bad disposition, and loss of condition. While no authentic cases of dogs dying from gross infestation have been observed by the writers, animals are known to have been destroyed becaused of weakened condition, ill temper, and unsightly appearance. Canine paralysis has also been attributed to the presence of numbers of ticks of this species.

Horses are often severely irritated by this tick. Attachment, particularly in well-groomed animals, usually takes place in the mane, tail, and fetlocks. Some horses thus infested keep rubbing, switching, and stamping almost constantly.

DISTRIBUTION

The American dog tick is widely distributed throughout the United States east of the Rocky Mountains, in western and northern California, and in parts of Oregon. There is one record of its occurrence in Mexico, and doubtless it is present in that country some distance south of the border on both the east and west coasts. This species has been taken in Alaska; also in Labrador, Nova Scotia, Ontario, and Manitoba, Canada.

This tick is most abundant along the eastern coast from Massachusetts to Florida, especially within a few miles of the beach. It is rather abundant over much of Texas and Florida. It is also abundant in some inland localities, such as southern Iowa and parts of Wisconsin and Minnesota. The tick has been observed in greatest numbers on certain islands off the coast of Massachusetts and the coast of South Carolina. It is interesting to observe the distribution and abundance of ticks in the New England States. The south side of Cape Cod and the islands to the south—Martha's Vineyard, Nantucket, and Naushon—are very heavily infested. Ticks are less abundant on the north than the south side of the cape, and there are few if any to be found north of Plymouth, or inland beyond Middleboro and Taunton, Mass. Along the coast there is a marked diminution in numbers from Marion, Mass., westward. They are reported to be rather numerous on islands in Narragansett Bay. A few are present on the west side of that bay and as far west as Stonington, Conn. This species is rather abundant on Long Island, especially on its eastern half. In Maryland the tick is abundant along the Chesapeake Bay and is rarely seen west of the Blue Ridge.

It appears likely that in the Eastern States low relative humidity is the most important factor in limiting distribution and abundance of this species.

The ticks are most numerous in areas covered with grass or underbrush, occurring less frequently in forests, where the species of mice that serve as hosts of the immature stages are less numerous.

The distribution, based on records collected by the Bureau of Entomology and Plant Quarantine, is shown in figure 1.

HOSTS

The dog is the preferred host of the adult ticks. A number of other animals of the larger species also serve as hosts for the adults. On the other hand, the immature stages (larvae and nymphs) engorge almost exclusively on small rodents such as mice (fig. 2). Apparently

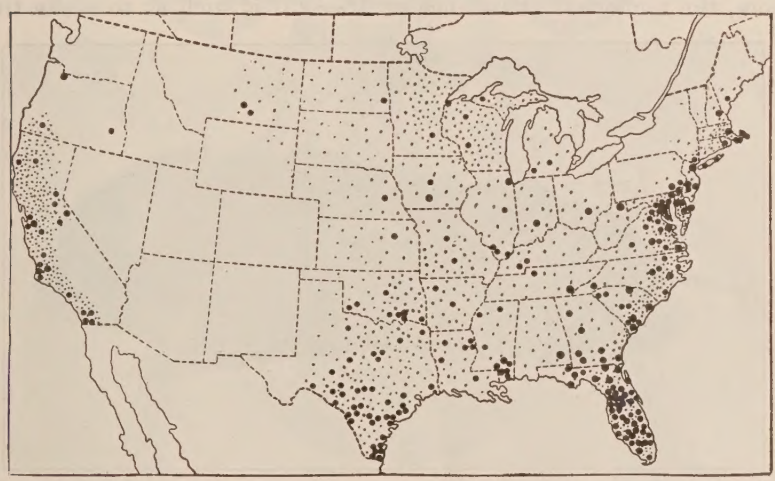

FIGURE 1.—Distribution of *Dermacentor variabilis* in the United States. Large dots indicate localities where collections were made by the Bureau of Entomology and Plant Quarantine; small dots indicate the probable range.

rabbits are of very little importance as hosts for this tick, and birds do not serve as hosts.

The relative frequency with which the adults of this tick are taken on different hosts is indicated by the following figures from the accession records of the Division of Insects Affecting Man and Animals of the Bureau of Entomology and Plant Quarantine: On dog, 218; man, 57; cattle, 31; coyote, 26; opossum, 18; hog, 18; horse, 16; racoon, 10; wildcat, 10; squirrel, 9; sheep, 7; badger, 6; wolf, 4; skunk, 4; deer, 3; fox, 3; cat, 2; peccary, 2; weasel, 2; ass, 1; leopard cat, 1; mountain lion, 1; Mexican lion, 1; mule, 1; rabbit, 1.

The following is a list of the collections of immature stages contained in the accession catalog, with the number of times larvae and nymphs, respectively, have been taken on the different hosts: White-footed mice (*Peromyscus*)—larvae 68, nymphs 18; meadow mice (*Microtus*)—12, 13; pine mice (*Pitymys*)—4, 8; house mouse (*Mus musculus*)—3, 0; kangaroo mouse (*Zapus*)—1, 1; mouse, species in doubt—5, 5; cottontail rabbit—3, 8; swamp rabbit—2, 1; cotton rat

(*Sigmodon hispidus*)—3, 1; Norway rat—2, 1; wood rat (*Neotoma*)—0, 1; squirrels—0, 7; cat—0, 2; shrew (*Blarina brevicauda*)—2, 1; sheep—0, 1 (unengorged); cattle—0, 1 (engorged); mole (*Scalopus aquaticus machrinus*)—1 (unengorged), 0.

While no collections have been made of nymphs or larvae attached to man, and such occurrences are certainly unusual, statements of residents on islands south of Cape Cod indicate that nymphs occasionally attach to man.

In localities where rats are abundant and live to a large extent in the open they are of some importance as hosts for larvae and nymphs.

Collections of mice in nature show that ground-surface-inhabiting species, such as the meadow mice (*Microtus*), are most important as hosts for both larvae and nymphs. Species that climb, such as white-footed mice (*Peromyscus*), are much less important. Furthermore, the numerical abundance of *Microtus* is such as to make this

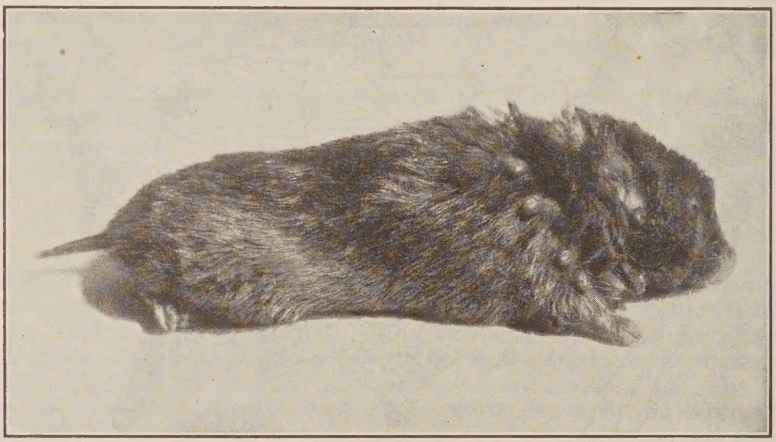

FIGURE 2.—A pine mouse with well-engorged nymphs of *Dermacentor variabilis* attached around the head. Four-fifths natural size.

group of mice of far greater importance as a host than any other. Even in laboratory tests the meadow mice prove in most cases to be the best hosts for larvae. In these tests from 400 to 2,500 larvae were put in a glass jar with a single mouse. The average number of larvae becoming engorged on the three species of mice was, meadow mouse 409, pine mouse 261, white-footed mouse 131. These three kinds of mice ranked in the same order as hosts for nymphs. Ticks have occasionally been found on house mice collected in fields, but have not been taken on the mice caught in houses. In the laboratory they seem to be slightly inferior to the white-footed mouse as a host. More than 100 larvae were found on a single meadow mouse (*Microtus pennsylvanicus pennsylvanicus*) caught in nature, at Fairfax, Va., on January 27, 1934.

Experience with the use of mice for the engorgement of ticks in the laboratory shows that when first captured they are better hosts than after they have been infested several times. This resistance to infestation apparently is due to the animals becoming more aware of the presence of the ticks and more active in trying to scratch them off.

LIFE HISTORY

Like other ticks of this family, *Dermacentor variabilis* passes through four stages, the egg, the larva or seed tick, the nymph, and the adult. The life history was worked out in some detail by Hooker, Bishopp, and Wood (*6*) in 1912, and a few observations were given by Hadwen (*5*) in 1913. In 1926 Zebrowski (*15*) published a report on the morphology of the species, and Cooley (*2*) briefly summarized the life history in 1932. The report of the Chief of the Bureau of Entomology for

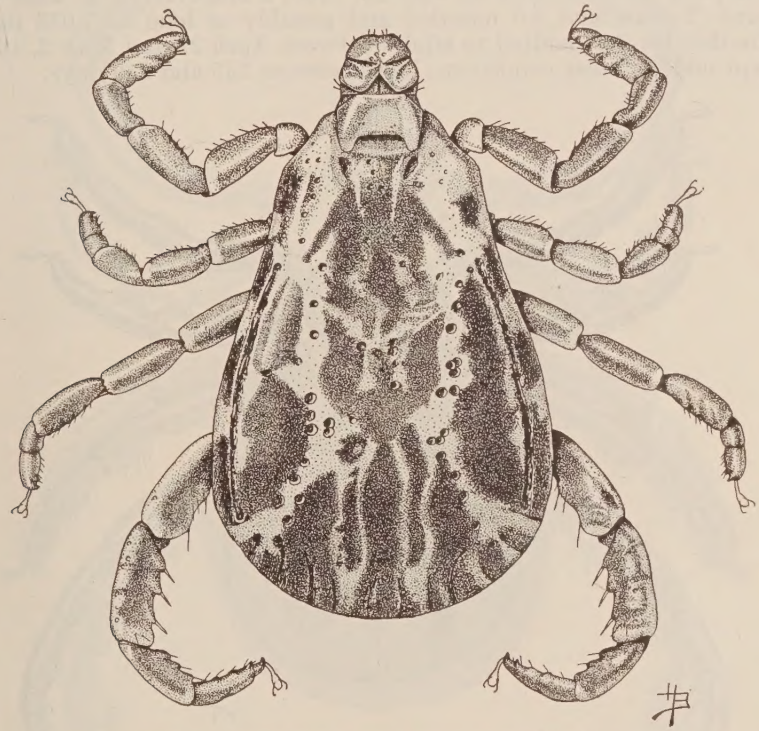

FIGURE 3.—Dorsal aspect of male *Dermacentor variabilis*. × 17.

1933 (*14*) discussed the host relationships, recording meadow mice, pine mice, and white-footed mice as the principal hosts of the immature stages in the East.

ADULT

The adult (male and female) is the only stage ordinarily seen. It is the common "wood tick" of the Central and Eastern States. It is often observed crawling on the clothing after one has been walking in the country and is commonly observed on dogs. The male (figs. 3 and 4) has a hard brown covering over the back which is marked with white lines. The female (figs. 5 and 6) is brown and bears a hard shield marked with white on the back at the head end. When unfed the males and females are about three-sixteenths inch in length. The bodies of the females when engorged (fig. 7) are bluish gray and

are about three-eighths inch in width by one-half inch in length. The males do not increase greatly in size upon feeding.

ADULT LONGEVITY

The unengorged adults are very long-lived if kept under favorable conditions. In one lot of one male and three females that molted to adults on September 6, 1933, kept in a shady, moist place in Maryland near the District of Columbia, one female was still alive on May 21, 1936, and all were dead on July 25, 1936, a longevity of at least 988 days (2 years and 8.6 months) and possibly as long as 1,053 days. Another lot that molted to adults between April 27 and May 2, 1934, kept under similar conditions, lived between 755 and 819 days.

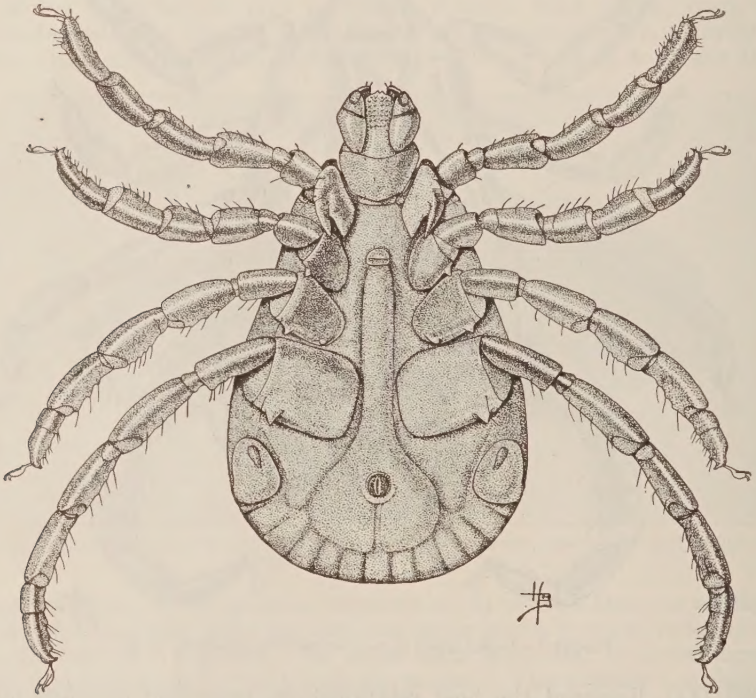

FIGURE 4.—Ventral aspect of male *Dermacentor variabilis*. × 18.

In the laboratory, probably owing to higher temperatures, longevity was not quite so great. One lot of eight males and eight females that molted from nymphs on April 6, 1934, lived for a period of between 929 and 986 days. One other lot lived for over 910 days, three lots between 850 and 880 days, two lots lived over 820 days, and two lots lived more than 700 days. Longevity in other lots ranged from 162 to 657 days.

The adults as well as other stages require considerable moisture. If kept under dry conditions, longevity is greatly reduced. In spring the adults are often found to be rather widely scattered over areas where favorable hosts abound. As the summer advances they are

observed to be concentrated in the lower bushy areas. There is some evidence that they move toward the moist, protected places, though it is likely that the localized distribution in midsummer is largely due to the death of the individuals in the drier, less favorable locations.

The longevity of adults which have attached to hosts is comparatively short. Most of the males and slightly engorged females which

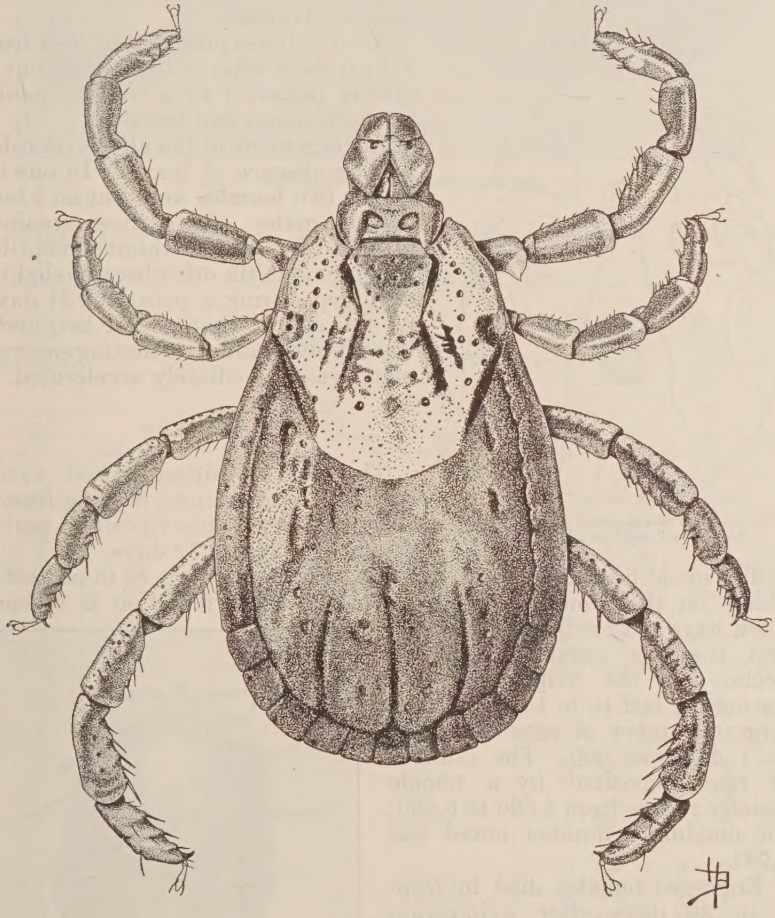

FIGURE 5.—Dorsal aspect of unengorged female *Dermacentor variabilis*. × 17.

are removed from a host die within a few weeks, though an occasional one may live for 5 or 6 months.

This is a matter of some economic importance because of the greater danger to man from the bite of an adult tick that has previously fed, since the organism causing Rocky Mountain spotted fever is activated in the tick by feeding, and such a partially fed tick attaching for a very short time may infect a person.

ENGORGEMENT AND MATING

The engorgement of females requires from 5 to 13 days. It is more difficult to get adults to attach late in the summer and in the fall than in the spring and early in the summer, and engorgement is usually slower. This is in accord with the reduced activity of adults in nature as the season advances.

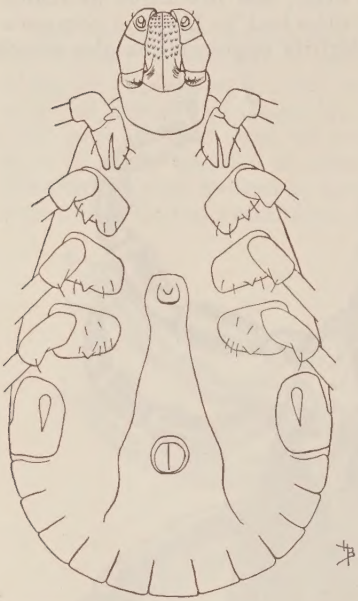

FIGURE 6.—Ventral aspect of unengorged female *Dermacentor variabilis*. × 18.

Mating takes place on the host from 4 to 6 days after attachment, but is always preceded by a feeding period for both males and females.

Engorgement of females is retarded by the absence of males. In one instance two females were put on a host without males. One of these remained attached for 6 days without perceptible engorgement, the other became slightly engorged during a period of 21 days. At the end of that period two males were applied, and after mating engorgement was immediately accelerated.

OVIPOSITION

The preoviposition period varies with the temperature, ranging from 3 to 24 days, and the oviposition period ranges from 14 to 32 days.

The ovoid brownish eggs are laid in large masses (fig. 8) in protected places on the ground. Maximum daily egg production is reached a few days after oviposition begins, and there is usually a marked decline in the oviposition rate during the last 10 to 15 days. The largest number of eggs deposited in 1 day was 800. The number of eggs deposited by a female usually ranges from 4,000 to 6,500; the maximum number noted was 6,941.

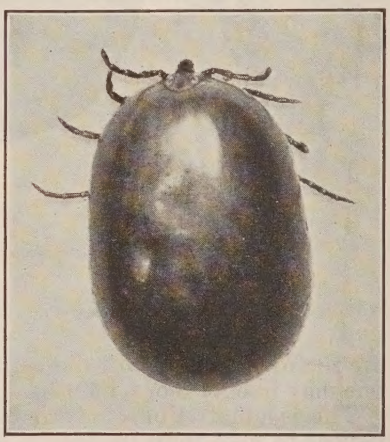

FIGURE 7.—Engorged female *Dermacentor variabilis*. × 3.

Engorged females died in from 3 to 36 days after oviposition was completed. The total longevity of such individuals after dropping (leaving the host after becoming engorged) ranges from 25 to 58 days.

Some typical records on the preoviposition, incubation, and larval longevity are given in table 1. Daily oviposition records are given in table 2.

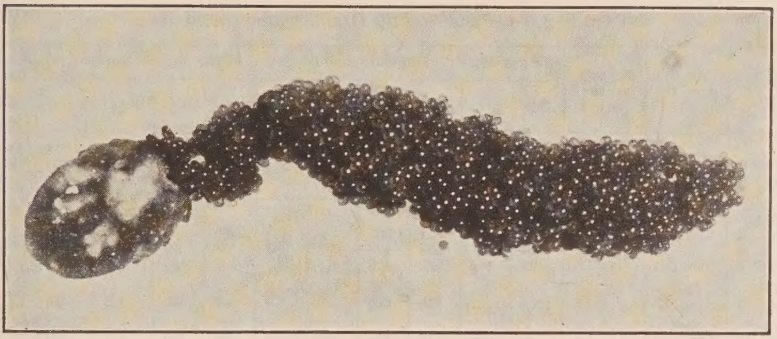

FIGURE 8.—Female *Dermacentor variabilis* and egg mass. × 2.

TABLE 1.—*Preoviposition, incubation, and larval longevity of Dermacentor variabilis*

Date female dropped or was picked off	Host	Date oviposition began	Preoviposition period	Date hatching began	Incubation period	Date larvae were last noted alive	Date all larvae were noted dead	Larval longevity
1932		*1932*	*Days*	*1932*	*Days*	*1933*	*1933*	*Days*
June 17	Dog	June 22	5	July 21	29	Feb. 21	Mar. 13	215–235
						1932	*1932*	
July 24	do	July 30	6	Aug. 26	27	Nov. 21	Nov. 28	87–94
1933		*1933*		*1933*		*1934*	*1934*	
Apr. 28	do	May 5	7	June 11–13	37–39	Apr. 23[1]		314
Apr. 29	do	May 12	13	June 16–17	35–36	May 28	June 28	345–377
May 10	do	May 17	7	June 22	36	do	do	340–371
Do	do	May 20	10	June 23	34	do	do	339–370
June 11	do	June 21	10	July 21	30	do	do	311–342
July 8	Horse	July 16–17	8–9	Aug. 13–14	27–29	June 28[1]		318
July 13	Dog	July 20	7	Aug. 15	26	May 7	May 28	265–286
Aug. 13	do	Aug. 19	6	Sept. 21	33	do	do	228–249
Do	do	Aug. 18	5	Sept. 18	31	May 28	June 28	252–283
1934		*1934*		*1934*		*1935*	*1935*	
May 12	do	June 5	24	July 5	30	Apr. 16	May 20	285–319
May 24	do	June 4	11	June 30–July 2	26–28	do	do	288–324
June 2	do	June 10	8	July 6	26	May 20	June 28	318–357
Do	do	do	8	July 7	27	Apr. 16	May 20	283–317
Do	do	June 11	9	July 8	27	May 20	June 28	316–355
						1934		
June 8	Horse	June 14	6	July 13	29	Dec. 11	Jan. 24	151–195
						1935		
July 15	Dog	July 20	5	Aug. 17	28	Apr. 16	May 20	242–276
July 18	Guinea pig	July 23	5	Aug. 19	27	May 20	June 28	274–313
July 19	do	do	4	Aug. 20	28	Mar. 12	Apr. 16	204–239
Do	do	July 24	5	do	27	Apr. 16	May 20	239–273
July 21	do	July 25	4	Aug. 23	29	May 20	June 28	270–309
July 23	do	July 26	3	Aug. 25	30	do	do	268–307
Aug. 5–6	do	Aug. 12	6–7	Sept. 14	33	June 26[1]		285
Aug. 7	do	do	5	Sept. 16	35	May 20	June 28	246–285
Aug. 8	do	do	4	do	35	June 28	Aug. 14	285–332
Do	do	do	4	Sept. 17	36	Apr. 16	May 20	211–245
Aug. 9	do	Aug. 13	4	Sept. 19	37	May 20	June 28	243–282

[1] Larvae applied to host on this date and became engorged; therefore maximum longevity cannot be given.

TABLE 2.—*Oviposition by Dermacentor variabilis*

Date dropped or picked	Date first eggs deposited	Preoviposition period	Eggs deposited on the specified day after the female dropped engorged										
			5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
1933	*1933*	*Days*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
May 2	May 15	13	------	------	------	------	------	------	------	------	236	247	292
4	May 18	14	------	------	------	------	------	------	------	------	------	126	152
1934	*1934*												
Aug. 6	Aug. 11	5	45	445	554	265	375	589	360	357	388	542	405
6	---do-----	5	46	481	635	498	639	683	558	336	389	383	388
6	---do-----	5	399	752	621	429	676	595	496	190	479	293	373
1909	*1909*												
Aug. 10	Aug. 17	7	------	------	336	616	800	560	464	489	422	486	294
1911	*1911*												
May 22	May 28	6	------	600	246	324	722	370	498	522	487	452	382
22	May 30	8	------	------	------	239	653	379	413	457	528	335	278

Date dropped or picked	Date first eggs deposited	Preoviposition period	Eggs deposited on the specified day after the female dropped engorged										
			16th	17th	18th	19th	20th	21st	22d	23d	24th	25th	26th
1933	*1933*	*Days*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
May 2	May 15	13	148	183	231	------	845	400	391	557	368	446	------
4	May 18	14	57	------	880	408	468	623	512	555	------	576	169
1934	*1934*												
Aug. 6	Aug. 11	5	288	423	466	265	256	83	111	89	28	28	26
6	---do-----	5	193	261	304	229	227	97	125	78	61	59	0
6	---do-----	5	140	110	140	64	39	18	28	17	14	16	0
1909	*1909*												
Aug. 10	Aug. 17	7	418	391	373	356	195	200	131	99	87	41	------
1911	*1911*												
May 22	May 28	6	214	252	165	131	58	20	------	------	------	------	------
22	May 30	8	218	211	159	174	107	86	57	38	------	------	------

Date dropped or picked	Date first eggs deposited	Preoviposition period	Eggs deposited on the specified day after the female dropped engorged									
			27th	28th	29th	30th	31st	32d	33d	34th	35th	36th
1933	*1933*	*Days*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
May 2	May 15	13	666	234	198	170	92	69	------	164	42	63
4	May 18	14	0	5	47	226	------	399	49	60	35	27
1934	*1934*											
Aug. 6	Aug. 11	5	31	35	32	16	14	11	8	3	7	11
6	---do-----	5	62	56	57	30	17	24	8	13	4	------
6	---do-----	5	0	16	5	------	------	------	------	------	------	------
1909	*1909*											
Aug. 10	Aug. 17	7	72	12	9	4	------	------	------	------	------	------
1911	*1911*											
May 22	May 28	6	------	------	------	------	------	------	------	------	------	------
22	May 30	8	------	------	------	------	------	------	------	------	------	------

Date dropped or picked	Date first eggs deposited	Preoviposition period	Eggs deposited on the specified day after the female dropped engorged										Total
			37th	38th	39th	40th	41st	42d	43d	44th	45th	46th	
1933	*1933*	*Days*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
May 2	May 15	13	46	39	23	------	6	------	------	------	------	------	6, 156
4	May 18	14	25	------	36	9	6	0	0	7	------	3	5, 460
1934	*1934*												
Aug. 6	Aug. 11	5	------	------	------	------	------	------	------	------	------	------	6, 556
6	---do-----	5	------	------	------	------	------	------	------	------	------	------	6, 941
6	---do-----	5	------	------	------	------	------	------	------	------	------	------	5, 910
1909	*1909*												
Aug. 10	Aug. 17	7	------	------	------	------	------	------	------	------	------	------	6, 855
1911	*1911*												
May 22	May 28	6	------	------	------	------	------	------	------	------	------	------	5, 443
22	May 30	8	------	------	------	------	------	------	------	------	------	------	4, 332

LARVA OR SEED TICK

The larva (figs. 9 and 10) is about 0.6 mm long. It differs from the other stages in having only three pairs of legs. In unfed individuals the color is pale yellow, with brick-red markings on the sides of the shield. Engorged specimens are slate gray.

LARVAL LONGEVITY

The larvae prefer moist shady places, and when exposed to dry conditions they die in a relatively short time. They tolerate much moisture, and during cool weather masses of them, largely covered by

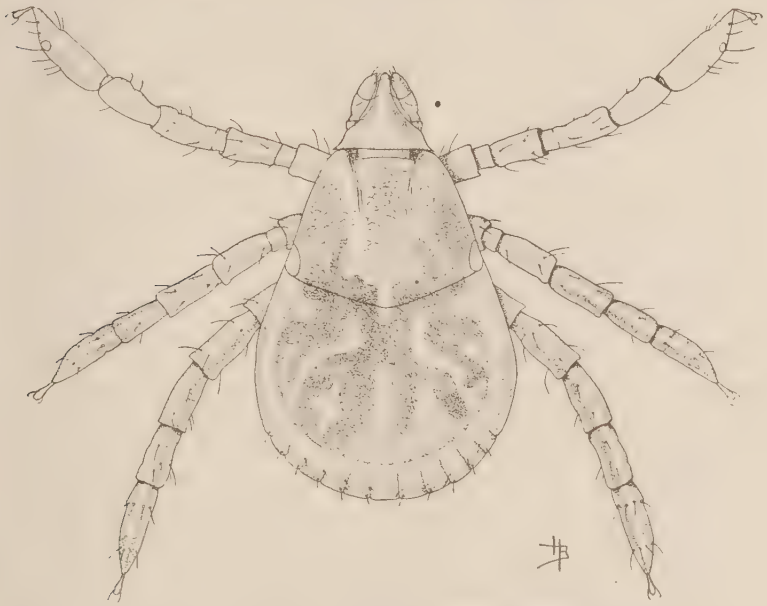

FIGURE 9.—Dorsal aspect of larva of *Dermacentor variabilis*. × 83.

water at intervals, will survive long periods. Larvae kept in tubes in the soil in favorable locations have been observed to live from 8 to 11 months. In the laboratory the longevity of larvae, if kept under moist conditions, is similar. The maximum period observed was between 345 and 377 days. Larvae 318 days old when put on a host attached and became engorged.

The larvae remain in masses on the soil or on low-growing vegetation while awaiting a host. They appear to scatter and crawl about more in warm than in cool weather.

LARVAL ENGORGEMENT

In a series of tests to determine how old larvae must be to attach, groups were put on suitable hosts during July 1934 on successive days after hatching. None of those 1 day old attached. A few of those 2 days old attached and became engorged. Those 3 or more days old attached and engorged readily, though the largest percentage of engorgement occurred among larvae 5 or more days old.

The shortest period of engorgement of larvae recorded was 2 days. This occurred in a series of infestations on a pine mouse. In most other cases the minimum engorgement period was 3 days. The maximum engorgement period was 12 days and the average was 4.14 days, based on 10,543 larvae, the engorgement time of which was recorded in these studies. Of these, 5,280 larvae dropped engorged on the fourth day. During winter the period of dropping of engorged larvae was distinctly prolonged; the period of engorgement, however, was practically identical whether the infested hosts were kept in a warm or a cool room.

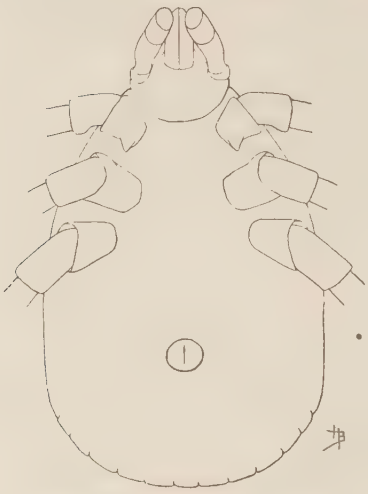

FIGURE 10.—Ventral aspect of larva of *Dermacentor variabilis*. × 85.

Larvae attach mainly around the head of a host, though some are found on the neck and shoulders and occasionally elsewhere on the body.

The engorged larvae seek protection on the soil surface and become quiescent in a few hours to 2 days, depending on the temperature.

Some records on engorgement of larvae are shown in table 3.

TABLE 3.—*Engorgement of larvae of Dermacentor variabilis*

Breeding No.	Date put on host	Host	Larvae that dropped engorged on the specified day following application										Total
			2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th	
	1933		*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
268	June 22	Pine mouse			12	8	1							21
271	June 28	do		76	58									134
290	July 17	do		191	225									416
358	Aug. 28	do	2	183	167	34	6							392
378	Sept. 11	do		70	127	14	2							213
392	Sept. 25	do		69	51	12								132
393	do	White-footed mouse		2	9	9	5							25
412	Dec. 27	Pine mouse		51	460	57	33	2						603
413	do	House mouse		15	178	29	24	3	0	6	0	0	1	256
	1934													
438	Jan. 5	Meadow mouse		58	292	106	55	44	22	4				581
439	do	White-footed mouse		1	33	27	28	20	20	9	17	8	[1] 6	169
441	do	Meadow mouse			295	86	50	35	16	16	5	2		505
442	do	White-footed mouse			31	29	15	10	7	8	6	6	[1] 4	116
499	Jan. 20	Meadow mouse		62	500	158	83	15	4	1				823
500	do	White-footed mouse		446	230	61	51	5	8	2				803
501	do	Meadow mouse		70	180	65	35	16	5					671
502	do	White-footed mouse		3	10	1	8	5	1					28
586	Feb. 12	Meadow mouse		62	635	42	13	2						754
590	do	Pine mouse		248	118	41	15	3						425
591	do	White-footed mouse		9	15	27	2	1	2	3	2			61
696	Mar. 20	Meadow mouse		145	67	89	9	1						311
698	do	White-footed mouse		8	3	1	2							14
746	Apr. 23	Meadow mouse		3	50	91	58	19	6	1				228
832	June 28	do				2	1							3
842	July 13	do		31	166	9								206
966	Nov. 2	do		26	306	29	31							392
978	Dec. 21	do		50	283	189	56							578
	1936													
1026	Mar. 31	White-footed mouse			26	23	12	17						78
1032	Apr. 8	do			7	10	4							21
1041	Apr. 16	White rat			2	2	6	7	4					21
	1937													
1142	Jan. 7	White-footed mouse			481	288	61	16						846

[1] Some larvae still attached on this day.

LARVAL MOLTING

The period from dropping to molting is markedly influenced by temperature, as shown in figure 11. The shortest molting period was 6 days. This occurred in July 1933, when the average daily mean temperature was 84.5° F., and in July 1934, when the mean temperature was 81.5° to 84°. The maximum period required for molting

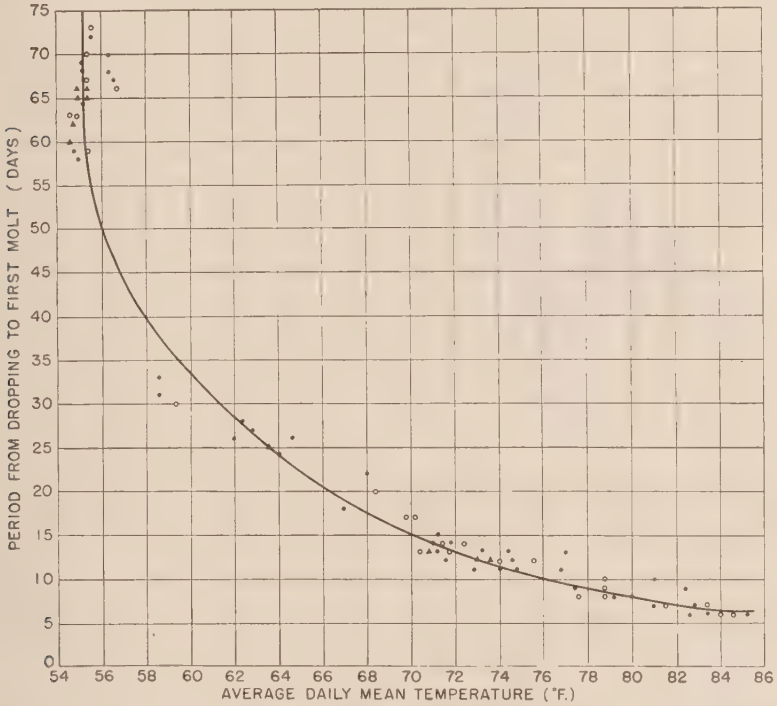

FIGURE 11.—Molting of larvae of *Dermacentor variabilis*. Dots represent single records, circles represent two records, and triangles represent three records.

was 87 days. During this period the minimum temperature was 36°, the maximum 75°, and the mean 55.1° F.

The marked effect of temperature on the molting period is illustrated by two lots of engorged larvae dropped on the same date. The one kept in the laboratory at an average daily mean temperature of 74.4° F. began molting on the sixteenth day, while the one kept out of doors at a mean temperature of 55.3° did not begin molting until the sixty-sixth day. Representative records of the molting of larvae at high and low temperatures are shown in tables 4 and 5.

TABLE 4.—*Molting of larvae of Dermacentor variabilis at moderate temperatures*

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping								
			6th	7th	8th	9th	10th	11th	12th	13th	14th
1933		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
July 19	Pine mouse	120		18	38	18	8	3			
20	do	71	5	28	21	12	1	1	1		
20	do	217	30	136	32	10	4	3			
Aug. 15	do	20			1	4	11	4			
30	do	105				10	82	9	1		
31	do	152			14	100	32	1			
Sept. 13	do	47								15	24
14	do	126							49	64	6
28	do	64								9	37
28	do	35								8	16
30	White-footed mouse	2								1	1
Oct. 1	do	5								2	1
1934											
Jan. 10[1]	Meadow mouse	106									
11[1]	White-footed mouse	28									
23[1]	do	446									
24[1]	Meadow mouse	300									
28[1]	White-footed mouse	8									
Mar. 23[1]	Meadow mouse	146							14	72	43
26[1]	do	9					1	3	3	1	1
Apr. 27	do	50								7	24
28	do	91							11	57	12
29	do	58						10	33	9	6
July 19	Pine mouse	11	11								
1936											
Apr. 4	White-footed mouse	26									
12	do	7									
13	do	10									

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping								
			15th	16th	17th	18th	19th	20th	21st	22d	23d
1933		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
July 19	Pine mouse	120									
20	do	71									
20	do	217									
Aug. 15	do	20									
30	do	105									
31	do	152									
Sept. 13	do	47	7	1							
14	do	126	2	3							
28	do	64	15	1	0	1	0	0	0	0	0
28	do	35	9	0	1	1					
30	White-footed mouse	2									
Oct. 1	do	5	2								
1934											
Jan. 10[1]	Meadow mouse	106	1	18	27	36	13	5	2	1	0
11[1]	White-footed mouse	28		4	5	4	1	2	1	1	1
23[1]	do	446			2	38	145	74	130	37	6
24[1]	Meadow mouse	300			4	29	42	127	67	14	5
28[1]	White-footed mouse	8								2	2
Mar. 23[1]	Meadow mouse	146	8	1	3	2	2	1			
26[1]	do	9									
Apr. 27	do	50	5	7	1	1	1	0	1		
28	do	91	5	2	1						
29	do	58									
July 19	Pine mouse	11									
1936											
Apr. 4	White-footed mouse	26									
12	do	7									
13	do	10									

TABLE 4.—*Molting of larvae of Dermacentor variabilis at moderate temperatures*—Continued

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping								
			24th	25th	26th	27th	28th	29th	30th	31st	32d
1933		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
July 19	Pine mouse	120									
20	do	71									
20	do	217									
Aug. 15	do	20									
30	do	105									
31	do	152									
Sept. 13	do	47									
14	do	126									
28	do	64	0	0	1						
28	do	35									
30	White-footed mouse	2									
Oct. 1	do	5									
1934											
Jan. 10 [1]	Meadow mouse	106	2	0	0	0	0	1			
11 [1]	White-footed mouse	28	1	1	2	1	2	1	0	0	0
23 [1]	do	446	1	0	1	1	1	0	2		
24 [1]	Meadow mouse	300	2	3							
28 [1]	White-footed mouse	8	0	0	0	3					
Mar. 23 [1]	Meadow mouse	146									
26 [1]	do	9									
Apr. 27	do	50									
28	do	91									
29	do	58									
July 19	Pine mouse	11									
1936											
Apr. 4	White-footed mouse	26									
12	do	7			1	4	0	0	0	1	
13	do	10		3	5	1	1				

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping				Larvae molted	Temperature from dropping to first molt		
			33d	34th	35th	36th		Maximum	Minimum	Average daily mean
1933		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	°*F.*	°*F.*	°*F.*
July 19	Pine mouse	120					85	90	79	84.2
20	do	71					69	90	81	84.5
20	do	217					215	90	81	84.5
Aug. 15	do	20					20	83	73	79.3
30	do	105					102	82	72	77.4
31	do	152					147	82	72	77.6
Sept. 13	do	47					47	83	67	73.1
14	do	126					124	83	67	73.1
28	do	64					64	81	66	71.8
28	do	35					35	81	66	71.8
30	White-footed mouse	2					2	77	66	70.6
Oct. 1	do	5					5	77	66	70.4
1934										
Jan. 10 [1]	Meadow mouse	106					106	82	65	73.5
11 [1]	White-footed mouse	28	1				28	83	65	74.4
23 [1]	do	446					438	83	60	73.0
24 [1]	Meadow mouse	300					293	83	60	72.5
28 [1]	White-footed mouse	8					7	80	60	70.6
Mar. 23 [1]	Meadow mouse	146					146	88	64	76.0
26 [1]	do	9					9	88	69	77.9
Apr. 27	do	50					47	86	59	71.3
28	do	91					88	86	59	71.8
29	do	58					58	86	61	72.7
July 19	Pine mouse	11					11	87	79	83.8
1936										
Apr. 4	White-footed mouse	26	2	16	3	1	22	87	36	58.6
12	do	7					6	87	45	62.0
13	do	10					10	88	45	63.5

[1] Kept in a heated room.

TABLE 5.—*Molting of larvae of Dermacentor variabilis at low temperatures*

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping								
			58th	59th	60th	61st	62d	63d	64th	65th	66th
1934		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Jan. 9	Meadow mouse	295		24	10	3	5	32	27	26	32
10	do	86						1	5	4	11
11	do	50									3
12	do	36								2	8
13	do	16						1	0	1	0
14	do	16					1	0	1	0	0
14	White-footed mouse	8									
23	Meadow mouse	70									2
24	do	480							33	35	43
25	do	65						1	1	1	4
26	do	35									1
29	do	66					2	9	25	11	4
30	do	58			3	6	13	25	2	1	1
Feb. 1	do	7	1	0	1	2	0	0	0	1	1

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping								
			67th	68th	69th	70th	71st	72d	73d	74th	75th
1934		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Jan. 9	Meadow mouse	295	35	24	15	7	11	7	8	2	2
10	do	86	7	7	2	4	6	2	0	0	1
11	do	50	0	1	4	4	1	0	0	0	7
12	do	36	0	3	0	3	0	3	4	1	3
13	do	16	2	0	0	0	0	0	1	0	1
14	do	16	0	2	0	0	0	1	2	1	0
14	White-footed mouse	8							1	0	2
23	Meadow mouse	70	7	7	9	29	5	2	3	0	2
24	do	480	55	82	125	21	7	11	13	9	10
25	do	65	11	18	6	4	0	1	2	4	5
26	do	35	9	4	4	3	0	4	5	0	1
29	do	66	2	3	2	3	0	0	0	0	0
30	do	58	1	1	1						
Feb. 1	do	7	1								

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping								
			76th	77th	78th	79th	80th	81st	82d	83d	84th
1934		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Jan. 9	Meadow mouse	295	1	3	0	0	3	2	2	0	1
10	do	86	1	8	0	3	3	0	4	7	0
11	do	50	4	2	2	5	1	0	7	1	0
12	do	36	0	1	2	2	1	2	0	1	
13	do	16	1	1	1	0	1	1	0	1	
14	do	16	1	1	1	3	0	1	0	0	0
14	White-footed mouse	8	0	1	0	1	1	0	0	0	0
23	Meadow mouse	70	2	1	0	0	0	0	0	0	0
24	do	480	2	2	1	2	0	0	0	0	0
25	do	65	1	1							
26	do	35									
29	do	66	0	1							
30	do	58									
Feb. 1	do	7									

Date engorged larvae dropped	Host	Larvae dropped	Larvae that molted on the specified day following dropping			Larvae molted	Temperature from dropping to first molt		
			85th	86th	87th		Maximum	Minimum	Average daily mean
1934		*Number*	*Number*	*Number*	*Number*	*Number*	°*F.*	°*F.*	°*F.*
Jan. 9	Meadow mouse	295				282	75	36	54.6
10	do	86	1			77	75	36	54.6
11	do	50	1			43	75	36	55.1
12	do	36				36	75	36	55.0
13	do	16				12	75	36	54.8
14	do	16	1			16	75	36	54.7
14	White-footed mouse	8	0	1		7	75	36	55.5
23	Meadow mouse	70	0	1		70	75	36	55.3
24	do	480	0	0	1	452	75	36	55.1
25	do	65				60	75	36	55.0
26	do	35				31	75	36	55.3
29	do	66				62	75	36	54.9
30	do	58				54	75	36	54.8
Feb. 1	do	7				7	75	36	55.1

NYMPH

The nymph (figs. 12 and 13) is similar to the larva in appearance, but has four pairs of legs and is about 1.5 mm in length. Unengorged specimens are pale yellowish brown, with the hind border of the shield dark brown and the sides of the shield brick red. In living specimens the intestines are visible as brown bands through the body wall. Engorged individuals are slate gray.

FIGURE 12.—Dorsal aspect of nymph of *Dermacentor variabilis*. ×38.

FIGURE 13.—*A*, ventral aspect of a portion of a nymph of *Dermacentor variabilis*, ×36; *B*, stigmal plate, ×110.

NYMPHAL LONGEVITY

The maximum longevity of unfed nymphs kept in tubes on moist sand in the laboratory was between 274 and 309 days. Several other lots showed some nymphs surviving 259, 271, 245 to 275, and 259 to 291 days. The longevity of most of the nymphs did not exceed 6 months.

One lot of 36 nymphs which molted from larvae September 28 to 30, 1933, were kept in an unheated room until June 28, 1934, an interval of 271 to 273 days. Three nymphs were still alive at this time, and when put on a meadow mouse two of them engorged.

NYMPHAL ENGORGEMENT

The engorgement period of nymphs was between 3 and 10 days, with an average of 5.2 days. This is based on accurate records kept on 414 nymphs which became replete in laboratory tests.

Newly molted nymphs are relatively inactive for 1 to 4 days, but 1 nymph out of 15 applied to a host on the same day molting occurred became engorged. On the second day after molting, nymphs attached and engorged readily.

Records of the engorgement of nymphs are shown in table 6.

TABLE 6.—*Engorgement of nymphs of Dermacentor variabilis*

Date put on host	Host	Nymphs that dropped engorged on the specified day following application								Total
		3d	4th	5th	6th	7th	8th	9th	10th	
1933		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
July 17	Pine mouse		2	2						4
29	do		3	4						7
29	do			5	2					7
Aug. 14	do		2	2						4
1934										
Jan. 16	Meadow mouse			14	1	1				16
26	do		33	13	17	0	1	0	1	65
26	White-footed mouse		3	0	1					4
Feb. 5	Meadow mouse		3	10	5	5				23
28	do		4	20	5					29
28	do		1	17	8	3				29
Mar. 13	do		1	8	2					11
28	do			3	4	2				9
May 1	do		1	1	3					5
1	do			2	1	0	0	1		4
Apr. 23	do			3	4	0	1			8
May 9	do			14						14
16	do			7	1					8
29	do					1	2			3
June 13	do				7					7
Aug. 8	do			8	0	1				9
Sept. 10	do	2	4	1						7
16	do	1	4	1						6
1935										
June 11	Guinea pig				5	3	8	3		19

NYMPHAL MOLTING

The shortest molting period noted (2 instances) in the course of the tests here reported was 17 days. The maximum, minimum, and mean temperatures during each of these periods were 92°, 75°, and 83° F., respectively. Hooker, Bishopp, and Wood (*6*) have reported a minimum nymphal molting period of 16 days. The maximum molting period observed was 105 to 109 days. This occurred in the case of a lot of nymphs dropped on September 16, 1934. As noted in table 7, two of the nymphs molted on the thirtieth and thirty-first days and the other one did not molt until the period between December 30, 1934, and January 3, 1935. The molting period is greatly lengthened during cold weather. The relationship between the length of the period and temperature is practically identical with that of the larval molting period, as shown in figure 11.

Records of molting of nymphs in summer and in winter are given in tables 7 and 8, respectively.

TABLE 7.—*Molting of nymphs of Dermacentor variabilis in summer*

Date engorged nymphs dropped	Host	Nymphs dropped	Number and sex [1] of nymphs that molted on the specified day following dropping						
			17th	18th	19th	20th	21st	22d	23d
1933		*Number*							
Apr. 5	White-footed mouse	1							
June 26	Guinea pig	2					1 ♀	0	1 ♀
July 20	Pine mouse	2	1 ♀	0	1 ♂				
21	do	20			1 ♂,2 ♀	2 ♂,1 ♀	2 ♂	1 ♂,4 ♀	0
Aug. 2	do	3			1 ♂	1 ♀	1 ♂		
2	do	4				1 ♂	0	1 ♂,1 ♀	1 ♂
3	do	5					1 ♀	0	3 ♂
18	do	2					1 ♀	1 ♀	
18	do	2			1 ♂	0	0	1 ♀	
1934									
Apr. 2 [2]	Meadow mouse	3							
2 [2]	Pine mouse	4							
3 [2]	Meadow mouse	2							
29	do	4							
May 7	do	3							
14	do	14							
21	do	5							
June 4	Pine mouse	4					2 ♀	1 ♂,1 ♀	
19	Meadow mouse	5	1 ♀	1 ♂,3 ♀					
July 5	do	2		1 ♂	1 ♀				
Aug. 13	do	6							
13	do	8							
Sept. 13	do	2							
16	do	4							
20	do	3							

Date engorged nymphs dropped	Host	Nymphs dropped	Number and sex [1] of nymphs that molted on the specified day following dropping						
			24th	25th	26th	27th	28th	29th	30th
1933		*Number*							
Apr. 5	White-footed mouse	1							
June 26	Guinea pig	2							
July 20	Pine mouse	2							
21	do	20	1 ♂,1 ♀						
Aug. 2	do	3							
2	do	4							
3	do	5	0	0	1 ♀				
18	do	2							
18	do	2							
1934									
Apr. 2 [2]	Meadow mouse	3							
2 [2]	Pine mouse	4							
3 [2]	Meadow mouse	2							1 ♀
29	do	4							
May 7	do	3							
14	do	14					1 ♀	1 ♂,4 ♀	2 ♂,3 ♀
21	do	5	1 ♀	1 ♂	1 ♀	0	1 ♂		
June 4	Pine mouse	4							
19	Meadow mouse	5							
July 5	do	2							
Aug. 13	do	6					1 ♂	1 ♂,1 ♀	0	1 ♀
13	do	8			2 ♀		1 ♀	1 ♂	2 ♀	2 ♂
Sept. 13	do	2		1 ♂,1 ♀					
16	do	4							1 ♀
20	do	3			1 ♀	1 ♀			

[1] ♂=males; ♀=females.

[2] Kept in artificially heated room.

TABLE 7.—*Molting of nymphs of Dermacentor variabilis in summer*—Continued

Date engorged nymphs dropped	Host	Nymphs dropped	Number and sex [1] of nymphs that molted on the specified day following dropping							
			31st	32d	33d	34th	35th	36th	37th	38th
1933		*Number*								
Apr. 5	White-footed mouse	1					1♀			
June 26	Guinea pig	2								
July 20	Pine mouse	2								
21	do	20								
Aug. 2	do	3								
2	do	4								
3	do	5								
18	do	2								
18	do	2								
1934										
Apr. 2 [2]	Meadow mouse	3				1♀	1♂	0	1♂	
2 [2]	Pine mouse	4			3♀	1♀				
3 [2]	Meadow mouse	2	0	0	1♀					
29	do	4				1♀	0	1♂	2♂	
May 7	do	3		1♀	0	1♀	0	0	0	1♂
14	do	14	2♂	0	1♂					
21	do	5								
June 4	Pine mouse	4								
19	Meadow mouse	5								
July 5	do	2								
Aug. 13	do	6	2♀							
13	do	8								
Sept. 13	do	2								
16	do	4	1♂							(3)
20	do	3								(4)

Date engorged nymphs dropped	Host	Nymphs dropped	Nymphs molted			Temperature from dropping to first molt		
			♂	♀	Total	Maximum	Minimum	Average daily mean
1933		*Number*	*Number*	*Number*	*Number*	°*F.*	°*F.*	°*F.*
Apr. 5	White-footed mouse	1		1	1	85	58	72.3
June 26	Guinea pig	2		2	2	91	70	79.6
July 20	Pine mouse	2	1	1	2	92	75	83.2
21	do	20	7	8	15	92	75	82.7
Aug. 2	do	3	2	1	3	92	75	80.9
2	do	4	3	1	4	92	73	80.7
3	do	5	3	2	5	89	73	79.8
18	do	2		2	2	86	72	78.5
18	do	2	1	1	2	86	72	78.6
1934								
Apr. 2 [2]	Meadow mouse	3	2	1	3	88	66	75.8
2 [2]	Pine mouse	4		4	4	88	66	75.6
3 [2]	Meadow mouse	2		2	2	88	66	75.3
29	do	4	3	1	4	86	61	71.2
May 7	do	3	1	2	3	86	62	72.6
14	do	14	6	8	14	84	62	72.1
21	do	5	2	2	4	84	62	73.5
June 4	Pine mouse	4	1	3	4	86	72	77.5
19	Meadow mouse	5	1	4	5	92	75	83.0
July 5	do	2	1	1	2	90	75	82.2
Aug. 13	do	6	2	4	6	84	59	72.8
13	do	8	3	5	8	84	59	72.8
Sept. 13	do	2	1	1	2	79	61	69.8
16	do	4	1	2	3	76	56	68.8
20	do	3	1	2	3	76	56	68.7

[1] ♂=males; ♀=females.
[2] Kept in artificially heated room.
[3] 1 female molted 105 to 109 days after dropping.
[4] 1 male molted 100 to 105 days after dropping.

TABLE 8.—*Molting of nymphs of Dermacentor variabilis in winter on meadow mouse*

Date engorged nymphs dropped	Nymphs dropped	Number and sex [1] of nymphs that molted during specified periods after dropping								
		30 to 34 days	35 to 39 days	40 to 44 days	45 to 49 days	50 to 54 days	55 to 59 days	60 to 64 days	65 to 69 days	70 to 74 days
1934	*Number*									
Jan. 30	33				1♂	1♂, 3♀	1♀	2♂, 5♀	5♂, 5♀	2♂
31 [2]	30									
31	13						1♂	1♂, 2♀	1♂, 2♀	2♀
Feb. 1 [2]	3									
1	17						1♀	1♂, 2♀	2♂, 3♀	1♂, 3♀
9	48				3♂, 3♀	12♂, 7♀	3♂, 4♀	3♂, 3♀	2♂, 1♀	
9	8							1♂, 2♀		
10	15				2♀	3♂, 1♀	4♂	1♂		
26	9				2♀	2♂	1♂, 2♀	1♀	1♀	
Mar. 5	17	1♀		3♂, 3♀	2♂, 4♀	1♂, 1♀	1♂	1♀		
18	8	2♂, 2♀		1♂, 2♀		1♀				
19	3	1♀		1♂						

Date engorged nymphs dropped	Nymphs dropped	Number and sex [1] of nymphs that molted during specified periods after dropping						Period from dropping to molting			
		75 to 79 days	80 to 84 days	85 to 89 days	90 to 94 days	95 to 99 days	100 to 104 days	Maximum		Minimum	
								Male	Female	Male	Female
1934	*Number*							*Days*	*Days*	*Days*	*Days*
Jan. 30	33	1♂, 1♀		4♀	2♀			78	92	45	51
31 [2]	30				6♀	5♂, 13♀	2♂, 1♀	102	104	95	90
31	13	1♀						65	77	59	61
Feb. 1 [2]	3				1♀	1♀			95		92
1	17	2♂			1♀	1♀		76	96	62	56
9	48	3♂		2♂, 1♀	1♀			86	91	46	46
9	8	1♂		1♀		1♀	1♂	103	98	61	61
10	15	1♀	1♂	1♂			1♀	85	100	50	45
26	9							56	65	51	47
Mar. 5	17							56	60	40	38
18	8							41	50	37	36
19	3							43	33	39	33

Date engorged nymphs dropped	Nymphs dropped	Nymphs molted		Temperature from dropping to first molt		
		Male	Female	Maximum	Minimum	Average daily mean
1934	*Number*	*Number*	*Number*	°*F.*	°*F.*	°*F.*
Jan. 30	33	12	21	88	60	72.4
Jan. 31 [2]	30	7	20	80	36	59.0
Do	13	3	7	88	60	72.9
Feb. 1 [2]	3		2	80	36	59.6
Do	17	6	11	88	60	72.9
Feb. 9	48	28	20	88	60	73.1
Do	8	3	4	88	60	74.3
Feb. 10	15	10	5	88	60	73.2
Feb. 26	9	3	6	88	64	75.2
Mar. 5	17	7	10	88	64	75.5
Mar. 18	8	3	5	88	64	75.5
Mar. 19	3	2	1	88	64	75.6

[1] ♂=male; ♀=female. [2] Kept in a cold room.

The molting period of males and females was practically the same. The females appear to outnumber the males. Among 462 engorged nymphs the molting of which was recorded, 251 were females and 211 were males. Collections of unengorged ticks in nature also appear to indicate that the females outnumber the males.

SEASONAL INCIDENCE AND OVERWINTERING

A knowledge of the seasonal incidence of adult ticks is of much importance in the epidemiology of Rocky Mountain spotted fever and the control of that disease. The seasonal incidence differs in different parts of the country. In general, the adults of this species are most abundant in the spring and early in the summer. In Maryland and adjacent States the ticks begin to appear from the middle of March to the middle of April, depending upon the temperature. They usually reach maximum abundance the latter part of May or early in June and decline sharply in numbers after mid-July. Relatively few ticks are seen after August 1. Appearance is usually slightly later farther north along the Atlantic coast.

The seasonal incidence of adults in northern California appears to be similar to that in Maryland. In Iowa their activity continues later in summer.

The seasonal abundance of adults in the Central States is illustrated by results of a survey conducted at Osceola, Iowa, in 1934 by George S. Cantonwine. Ticks were collected daily from a dog and from 10 cows which were kept in the same pasture throughout the study. The first collections were made on June 6, when between 20 and 30 ticks were removed from each animal. The period of greatest abundance was from June 6 to June 14, as many as 64 ticks attaching to a single cow in 1 day. Ticks were slightly less abundant from June 15 to June 29, and the period from June 30 to July 6 showed a further slight decrease. A great decrease in abundance was noted between July 7 and August 3, and ticks were completely absent from August 4 to August 12, when the temperature reached 115° and 120° F. When the temperature dropped to normal on August 13, ticks reappeared, but were less numerous than before, and were collected in constantly dwindling numbers until September 24, after which no ticks were found.

In the South the seasonal activity is not so sharply restricted. In fact adults have been taken on hosts in Florida and Texas every month of the year. As a rule, however, they are more abundant in spring. The hot, dry weather of midsummer practically stops activity.

In the Southern States there is continuous but retarded breeding throughout the winter. In the colder parts of the country overwintering may take place in all stages except as eggs. As few females become engorged and lay eggs late in the summer, most egg masses hatch before winter sets in.

The adults, in the unfed state, seek protected places in the fall. They have been found in numbers completely quiescent deep down in clumps of bunch grass. When warmed they become active in a short time. Larvae and nymphs are to be found on mice and other small mammals throughout the winter. Groups of mice were collected in the District of Columbia and nearby Maryland and Virginia during the winter of 1933–34. Larvae and nymphs were found attached to 31 percent of these groups. During January as high as 102 larvae and nymphs were taken on a single meadow mouse. It was noted that the number of immature ticks on animals increased after periods of mild weather and was almost nil following severe weathers. It should be remembered that these mice remain active throughout the winter.

Since the development of larvae and nymphs toward molting progresses very little during cold weather and speeds up at higher temperatures, it appears that the ticks engorged during winter all molt during a comparatively short time in spring. This coincides with the finding in nature of large numbers of unfed adults and nymphs in spring, while seed ticks are relatively scarce.

NATURAL CONTROL

Hunterellus hookeri Howard is the only tick parasite that has been taken on *Dermacentor variabilis*. It readily attacks and develops in nymphs of this species under laboratory conditions. In nature collections have been made on Naushon Island, Mass., and Capers Island, S. C., where the parasite had been liberated 1 or 2 years previously. The South Carolina collection consisted of a single nymph taken on a cow. It yielded six parasites. This parasite species was liberated by F. Larrouse on Cape Cod, Mass., and adjacent islands in 1929; and while it successfully overwintered there (*7*), it has not been recovered in collections of nymphs made during the last 3 years. The difficulty of controlling the American dog tick by artificial means makes desirable further work with this parasite.

Predators such as poultry, birds, and mice doubtless destroy many American dog ticks, particularly the engorged females.

Probably climatic factors are of most importance among the natural control agencies. Of these lack of moisture is dominant. Excessive dryness is very destructive to all stages. Probably this is the principal limiting factor in Western States. As previously indicated, desiccation greatly shortens the length of life of seed ticks, nymphs, and adults, and eggs fail to hatch under excessively dry conditions.

The American dog tick is very resistant to cold, as indicated by the fact that it is abundant in such Northern States as Massachusetts, Wisconsin, and Minnesota.

No appreciable mortality due to cold occurs among larvae, nymphs, or adults exposed during winter at Washington, D. C.

Unengorged larvae and nymphs were subjected to low temperatures in a refrigerator for periods of 24 to 72 hours. Temperatures above 0° F. did not kill any individuals, temperatures ranging from −1° to −9° killed some but not all of the larvae and nymphs exposed, while temperatures below −10° produced 100-percent mortality. Exposure to temperatures low enough to kill 75 percent of the nymphs in one lot did not affect the ability of the surviving 25 percent to attach and engorge.

Measurements of the undercooling and freezing points of females were made with a thermocouple and potentiometer. In the case of unengorged females the undercooling point ranged from 19.7° to 3.5° F., the average being 9.3°, and the freezing point ranged from 21.7° to 11.8°, the average being 16.2°. Among the engorged females the undercooling point ranged from 22.1° to 3.9°, with an average of 13.4°; the freezing point ranged from 25.1° to 16.8°, the average being 21.7°.

ARTIFICIAL CONTROL

The control of a tick with such general host habits and with such longevity and wide distribution as the American dog tick is a difficult matter. In areas where there is an abundance of both small and large

wild animals its complete control appears almost impossible, but further experimental work may indicate some practical method of greatly reducing its numbers.

In certain areas where the tick is abundant, large wild mammals that are suitable for the engorgement of adult ticks are few or absent. This is true on certain islands along the coast, as on Martha's Vineyard and Nantucket, Mass. Under such conditions the strict control or treatment of dogs, which are by far the most important host of the adults, so as to prevent the engorgement of adults would, it is believed, result in reasonably good control of the pest. This measure might well be coupled with campaigns against the meadow mice—the principal host of the immature stages.

The thorough application of derris as a powder or wash is effective in destroying the ticks already attached and in preventing the reinfestation of dogs for short periods. Application is easier when the powder is used, and ticks that actually come in contact with the derris will be killed, but the animals are less thoroughly covered than when the material is used as a wash or dip. In addition to giving a more complete treatment at the time of application, the derris applied as a wash is retained on the hair and skin longer than the powder and has a more extended repellent action. When used by either method, derris is more effective against flat or slightly engorged ticks than against the fully engorged females, so, in order to prevent all reproduction, treatments should be given before females become well engorged. The powder should be applied at intervals of 2 or 3 days and the wash or dip at intervals of 5 or 6 days. Such treatment will greatly reduce the number of ticks becoming attached, and prevent engorgement and reproduction.

The derris powder should have a rotenone content of at least 2 percent. An effective dip or wash can be made by dissolving an ounce of soap in a gallon of water and adding 2 to 4 ounces of derris powder of which the rotenone content is 4 percent.

Coal tar-creosote dip and the standard arsenical dip used to control cattle ticks are also useful in killing ticks on dogs, but from a few preliminary observations these materials do no appear to be as effective as derris.

If arsenical dip is used, care must be taken to keep the dogs on their feet until the dip dries, or burning may result.

Clearing away undergrowth and keeping grass cut closely, especially near habitations, camps, walks, etc., greatly reduces the chance of human infestation. The use of clothing calculated to exclude ticks, when one finds it necessary to traverse tick-infested areas, helps protect against attack. Watchfulness for ticks will usually result in their removal before they attach. Frequent examination of the body, and especially the head, is important so as to remove ticks before they have attached long.

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26

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